2004 Return to *Titanic* Expedition

Galvanic vs. *Titanic*?

Focus
Galvanic exchange and deterioration of the *Titanic*

Grade Level
7 - 8 (Physical Science)

Focus Question
How does the variety of metals used in constructing the *Titanic* contribute to deterioration of the shipwreck?

Learning Objectives
Students will be able to describe galvanic exchange and explain how it contributes to deterioration of the *Titanic*.

Given two dissimilar metals and information on their position in an Electromotive Series, students will be able to predict which of the metals will deteriorate if they are placed in a salt solution.

Students will be able to list two other processes that contribute to deterioration of the *Titanic*.

Materials
- ❒ Copper metal (tack, washer, wire)
- ❒ Zinc metal (galvanized nail or washer)
- ❒ Iron metal (non-galvanized nail)
- ❒ Aluminum metal (aluminum nail, bolt, or washer)
- ❒ 500 ml approximately 3 M hydrochloric acid (see Learning Procedure)
- ❒ Four 100 ml beakers or similar-size glass jars
- ❒ Safety goggles

Audio/Visual Materials
- ❒ Overhead projector and transparencies

Teaching Time
One 45-minute class period

Seating Arrangement
Classroom style

Maximum Number of Students
30

Key Words
Titanic
Galvanic exchange
Electromotive series
Oxidation
Corrosion

Background Information
At 11:40 pm on April 14, 1912, RMS *Titanic* struck an iceberg off the coast of Newfoundland. Two hours and 40 minutes later, the great liner sank 3,900 meters to the bottom of the North Atlantic Ocean. Thought to be unsinkable, *Titanic* had not survived her maiden voyage. Neither did 1,522 passengers and crew members who also perished on that cold April morning.

In 1985, *Titanic* was seen again by explorers from the Woods Hole Oceanographic Institution and the Institut Français de Recherches pour L'Exploitation des Mers. Using the remotely operated vehicle (ROV) Argo, the explorers made dramatic video recordings showing changes brought about by 73 years in the deep ocean. Since the initial discovery in 1985, *Titanic* has been visited by numerous other expeditions, many of which have taken away considerably more than video images. At the end of 2002, an estimated 6,000 artifacts had been removed from the *Titanic* wreck site. These activities have stirred controversy, since the *Titanic* shipwreck is unquestionably a gravesite as well. This fact is underscored by video images of paired shoes (for example, at http://members.aol.com/tinsleyfam/titanicpresent.html lying on the ocean floor in positions that suggest the shoes have not moved since the person wearing them landed on the bottom. Visit http://www.imacdigest.com/archrepo.html for a list of artifacts removed from the *Titanic* site in 2000.

In addition to damage caused by recent human activities, the remains of *Titanic* have been subjected to more than 90 years of natural degradation processes as well. One of the most conspicuous processes is caused by complex communities of bacteria and fungi that produce structures called "rusticles" that superficially resemble icicles or stalactites. Rusticles are built up in ring structures and are highly porous with channels and reservoirs that allow water to flow through. Up to 35% of rusticles' mass consists of iron compounds (iron oxides, iron carbonates, and iron hydroxides). The remainder is biomass of bacteria and fungi. Rusticles grown in laboratories have been found to continuously release a red, powder-like material as well as a yellowish slime. The iron content of these materials is 20 ± 5% and 8 ± 3% respectively. These releases total between 0.02% and 0.03% of the rusticles' biomass per day. Based on these observations, it has been estimated that all of the iron in *Titanic's* bow section could be removed in approximately 280 to 420 years. Experiments are underway at the *Titanic* site to measure the actual rate of iron removal from the ship due to rusticles. Whatever the rate, it is clear that *Titanic* is slowly being recycled back to nature.

Another natural degradation process known as "galvanic exchange" (or "galvanic coupling" or "galvanic corrosion") is also at work on *Titanic*. This process results from different metals in electrical contact with each other in seawater. Metals can be classified into an "Electromotive Series" according to the strength with which they "hold on" to their electrons. Metals lower in the Series tend to give up their electrons more readily than metals that are higher in the Series. When two metals with different electromotive strengths are electrically connected and submerged in an electrolyte (such as seawater), electrons will flow from the metal lower in the electromotive series, causing this metal to form oxides or other compounds in a process we know as corrosion (this is also the process through which batteries produce an electric current). Besides the iron in its hull, *Titanic* contains many other metals such as lead, bronze, copper, and brass that are higher in the Electromotive Series than iron. As a result, the steel in *Titanic's* hull is degraded as iron is replaced by other compounds formed through galvanic exchange.

It has been suggested that galvanic exchange was the real reason *Titanic* sank in the first place. Since the ship was held together by 3 million rivets made with wrought iron (which is a different material than the hull plates), galvanic exchange could have taken place between the dissimilar metals of the hull and rivets causing the rivets to weaken. In fact, *Titanic* sat in seawater for a year after her hull was launched while the interior was furnished. One of the last photos taken before the ship's maiden voyage shows a pattern that may suggest the rivets were rusting faster than the hull plates. When *Titanic* collided with the iceberg, the weakened rivets could have popped (which would account for a clinking sound reported by some survivors). An opening just an inch wide between the hull plates would have been enough to sink the ship…and video images of the wreckage show a narrow opening in the unburied part of the bow, as well as preferential corrosion of the rivets in some areas. For more information on this theory, visit http://www.corrosion-doctors.org/Landmarks/titan-sinking.htm.

The mission of the 2004 Return to *Titanic* Expedition is to assess changes that have occurred at the RMS *Titanic* wreck site since 1985, and to investigate natural degradation processes as well as changes caused by human activity.

In this lesson, students will investigate the chemical activity of several metals, and use their observations to arrange the metals in an Electromotive Series.

Learning Procedure

[**NOTE:** Step 4 of the following procedure is designed as a demonstration to avoid having students work with corrosive materials. Goggles must be worn throughout portions of the activity involving work with hydrochloric acid. This solution can burn skin and damage clothing. Fumes can also be caustic and/or irritating. Do Step 4 in a well-ventilated area, preferably under a fume hood.]

1. Prepare approximately 3 M hydrochloric acid solution by diluting 250 ml concentrated HCl to 1.00 liter with distilled or deionized water. Muriatic acid from hardware stores is approximately 8 M HCl. Dilute 375 ml muriatic acid to 1.00 liter to make approximately 3M solution.

   Clean metals with steel wool to remove any surface oxide coatings that might interfere with the test.

   Download a copy of the press release, "Return to *Titanic* Mission to Document Wreck's Destruction" from http://news.nationalgeographic.com/news/2004/04/0423_040423_titanicscience.html. Make an overhead transparency of the title and first paragraph.

   Visit http://oceanexplorer.noaa.gov and www.returntotitanic.com for up-to-date information on the 2003 and 2004 Return to Titanic Expeditions.

2. Briefly review the history of *Titanic*, its sinking, discovery of the shipwreck in 1985, and human activities at the site following this discovery. Show students the overhead transparency, and ask what processes might be responsible for the "alarming and possibly increasing rate of deterioration. Students should recognize that both natural and human-induced processes may be involved, and may distinguish between galvanic action and "rusting." If you have serious *Titanic* fans in your class, they may also know about rusticles.

3. Review the concept of oxidation and reduction. Be sure students understand that the term "oxidation" means loss of electrons. While oxygen is often involved in this process, oxidation can also take place in the absence of oxygen. Tell students that they are going to make observations that should allow them to classify different metals according to how easily the metals give up their electrons. Be sure students understand that the $H+$ ions from the HCl solution will be reduced (gain electrons) to form hydrogen gas at a rate that depends upon how readily electrons are provided by the metals being tested.

4. Place a piece of each metal to be tested in a 100 ml beaker or similar-sized glass jar. Add just enough 3 M HCl solution to cover the metal. Have students record the relative activity of each metal according to the rate at which hydrogen is released.

5. Have students rank the metals from lowest (least amount of hydrogen produced) to highest electromotive activity.

6. Have students answer the following questions:
   a. Boats often have bars of zinc attached to metals parts below the water. Why? [*Zinc is low on the electromotive scale, so zinc loses its electrons more easily than other metals and protects these metals from corrosion.*]

   b. Bronze is slightly higher than copper on the electromotive scale. What would happen if a bronze propeller were attached to a steel drive shaft on a ship? [*The shaft would corrode because steel is lower on the electromotive scale than bronze.*]

c. How could this be prevented? [*by attaching zinc to the drive shaft*]

d. What would happen if a zinc-plated steel washer were used underwater with a stainless steel bolt? [*The zinc would eventually corrode away, allowing the steel washer to rust and weaken the connection.*]

e. List five items that might be found on *Titanic* that you would expect to experience little or no corrosion [*any metallic items made from bronze, copper, gold, or silver; as well as durable non-metallic items such as china or glass; artifacts removed from the ship also include shoes and clothing*]

The BRIDGE Connection

www.vims.edu/bridge/ – In the Navigation toolbar, click on "Ocean Science Topics," then "Human Activities," then Archeology. Also, search keyword "*Titanic*" in the "Search" box for more locations on the BRIDGE site dealing with *Titanic* topics.

The "Me" Connection

Have students write a short essay describing ways in which corrosion might affect their own lives, and what is (or could be) done to avoid these impacts.

Connections to Other Subjects

English/Language Arts, Social Studies, Life Science

Evaluation

Student reports in Steps 5 and 6 provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov and www.returntotitanic.com to find out more about the 2004 Return to *Titanic* Expedition, and to learn about opportunities for real-time interaction with scientists on current Ocean Exploration expeditions.
2. Have students investigate initiatives to protect the wreck of *Titanic*, and discuss the merits of salvage vs. protection.
3. Have students investigate one or more persons who were aboard *Titanic* when the ship sank, and prepare a report on their activities on April 14 and 15, 1912.

Resources

http://www.corrosion-doctors.org/ – A web site about corrosion causes and solutions, with modules designed for training in corrosion science and engineering

http://www.encyclopedia-titanica.org/index.php — Encyclopedia Titanica web site with biographies, research articles and ongoing discussions about *Titanic*

http://score.rims.k12.ca.us/activity/bubbles/ – Marine archaeology activity guide based on investigations of the wreck of a Spanish galleon; from the Schools of California Online Resources for Education website

http://www.titanic1.org/ – *Titanic* Historical Society

http://www.titanicinquiry.org/ – *Titanic* Inquiry Project

http://www.skarr.com/titanic/ – The *Titanic* Information Site

http://ourworld.compuserve.com/homepages/Carpathia/ – *Titanic* Tidbits

http://www.sciencedrive.com/mitchk/titanic.htm#titanic – The Unsinkable RMS *Titanic*

http://members.tripod.com/~hoko/index-4.html – *Titanic* Links

http://www.titanicscience.com/TSci-ActivityGuideFinal.pdf – Maryland Science Center's *Titanic* Science Teacher Activity Guide

http://www.jasonproject.org/jason_project/jason_project.htm – web site for the multidisciplinary JASON project designed to expose students to leading scientists who work with them to examine the Earth's biological and geological development

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National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Properties and changes of properties in matter
- Transfer of energy

Content Standard C: Life Science

- Diversity and adaptations of organisms

Content Standard E: Science and Technology

- Abilities of technological design

Content Standard F: Science in Personal and Social Perspectives

- Natural hazards
- Risks and benefits

For More Information

Paula Keener-Chavis, National Education Coordinator/Marine Biologist
NOAA Office of Exploration
2234 South Hobson Avenue
Charleston, SC 29405-2413
843.740.1338
843.740.1329 (fax)
paula.keener-chavis@noaa.gov

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